Assessing the Performance of Building Mechanical Systems in an Office Building

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I. ABSTRACT

The purpose of this research is to evaluate the performance of building mechanical systems in an office. The mechanical systems include eleven variable air volume (VAV) units that provide outdoor air to the office spaces and induction units that provide heating and cooling to the office spaces. This study presents the data collection, sensor installation, and analyses of the ventilation, heating, and cooling provided to the spaces. Differential pressure transducers, temperature sensors, and heat flux sensors were installed on-site to monitor these systems at every one-minute and five-minute interval. The process of analyzing datasets from these sensors is automated and used to calculate ventilation, heating, and cooling under current building automation sequences of operation. The results of this study will aid our understanding of the impacts of different building mechanical systems, occupancy patterns, time of the day on the ventilation, heating, and cooling use for the selected building.

II. INTRODUCTION

This study aims to develop a reliable method of evaluating and analyzing the mechanical systems of an office building. The space studied for this project is divided into eleven thermal zones. Each zone is served by a Variable Air Volume (VAV box) connected to a number of ceiling diffusers to provide for space conditioning and outdoor air requirements. In addition, induction units installed around the perimeter next to the windows around the South and West facades provide heating and cooling to the space.

III. METHODS

The VAV differential pressure, temperature, and relative humidity are monitored using Onset data loggers and gateways. The differential pressure is monitored using Veris sensors connected to Onset MX 1104 data loggers fitted in custom-made boxes. The temperature and relative humidity for one ceiling diffuser connected to each VAV box are monitored using the same data loggers.
Ten Fluxteq heat flux sensors are currently in operation: six are installed inside induction units across three rooms, three are installed at windows across two rooms, and one is installed outside the cover of an induction unit.

IV. ANALYSIS

The rate of heat transfer at windows or induction units is calculated by multiplying the measured area with the heat flux recorded by the Fluxteq sensors. The volumetric flow rate of the air in the VAV boxes, Q is calculated using data from the differential pressure sensors as follows:

$$V = 4005 \times \sqrt{dp} \tag{1}$$

$$Q = V \times A \tag{2}$$

where V = velocity of air, foot per minute (fpm)
dp = differential pressure, inches of water (in w.c.)
A = cross-sectional area of the VAV box, ft^2

The datasets collected for differential pressure, temperature, relative humidity, heat flux, and the calculated airflow and heating/cooling loads are plotted using Python scripts. Various types of graphs are used: scatter plots, heat maps, and box plots. As an example, the hourly rate of heat transfer at an induction unit in a private office room over a period of 26 days is shown in Figure 1. A negative value for heat transfer signifies cooling. The larger magnitude of heat transfer during the day illustrates the higher usage of the induction unit for space conditioning in those times; outside of working hours, the output at the induction unit changes little.

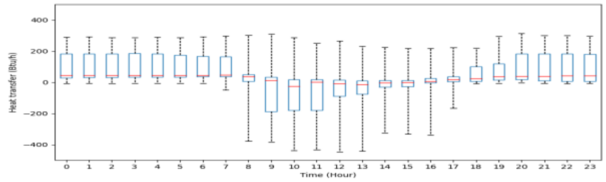

Figure 1: Hourly heat transfer at an induction unit

The temperature and relative humidity measured in one month at a diffuser connected to VAV box no. 10, which is located in a lounge area, are represented in Figures 2, 3, and 4. The initial measurements do not fluctuate much as the space was unoccupied around this time. For the latter part, the hourly temperature in Figure 3 shows how the temperature of the air supplied to the space falls during the day when occupancy is highest, to accommodate for the greater heat gain due to occupants and equipment usage. Similarly, Figure 4 illustrates how the RH rises during occupied hours.

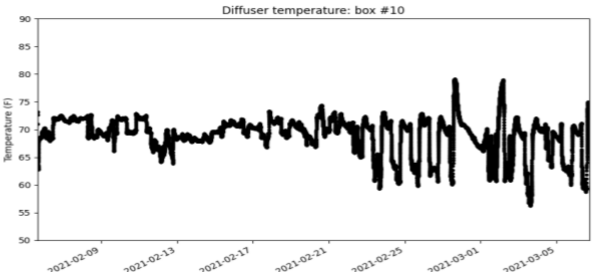

Figure 2: Diffuser temperature in a lounge area

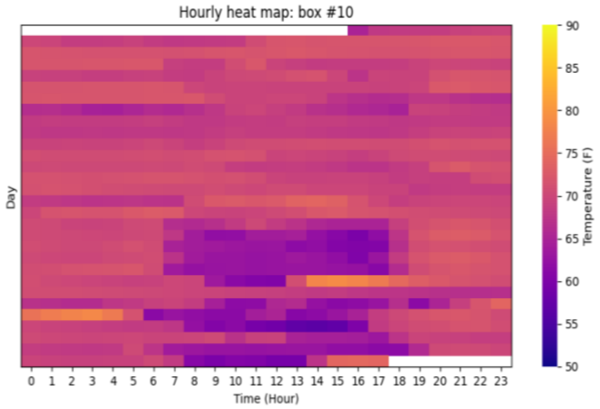

Figure 3: Hourly temperature of air supplied to a lounge area

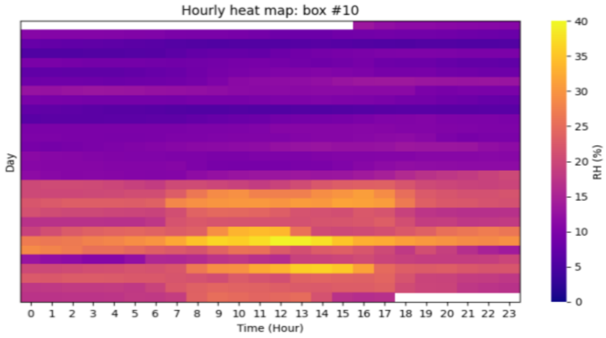

Figure 4: Hourly relative humidity of air supplied to a lounge area

V. CONCLUSION

The preliminary data shows how factors such as occupancy and time of day influence space loads as well as airflow requirements. Greater occupancy increases the load and thus the facets of air supply; the variation in outside temperatures affects loads throughout the day, impacting heating and cooling device usage. Further analysis will yield a better understanding of the effect of such elements on the operation of building mechanical systems and can be used to monitor as well as improve on specific building facilities in the future.